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COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE

GLOBAL CHANGE: PARTICIPATION OF DEVELOPING COUNTRIES AND POSSIBILITIES OF ENHANCING IT

Note by the Secretariat

1. The Working Group of the Whole to Evaluate the Implementation of the Recommendations of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82), at its eighth session (A/AC.105/571, annex II, para. 17) proposed that several studies on space applications should be undertaken by the Office for Outer Space Affairs in view of the recommendations adopted at the workshops, seminars, symposia and conferences organized by the United Nations Programme on Space Applications. The Working Group of the Whole identified a number of possible subjects for such studies, including the subject of the participation of developing countries in the global change programme and possibilities of enhancing it.

2. The report of the Working Group of the Whole was adopted by the Scientific and Technical Subcommittee in its report on the work of its thirty-first session (A/AC.105/571, para. 22), and the recommendations were endorsed by the Committee on the Peaceful Uses of Outer Space (COPUOS) in its report on the work of its thirty-seventh session[1] and by the General Assembly in its resolution 49/34 of 9 December 1994.

3. The present study has been prepared by the Secretariat in response to the request of the Working Group of the Whole. Its purpose is to stimulate the greater participation of specialists from developing countries in the Global Change Programme, which is an important part of the efforts to understand and preserve the global environment for humanity. The study was prepared using a variety of national and international sources, which are listed in the selected bibliography at the end of the study. It was also sent in draft form to external experts for comments. A summary of the study is provided below.

SUMMARY OF THE STUDY

4. The International Geosphere-Biosphere Programme (IGBP): A Study of Global Change was established in 1986 by the International Council of Scientific Unions (ICSU) to address the challenges of global change, recognizing that the complexity and importance of this topic required an international approach, with an emphasis on a soundly based framework for research planning, implementation and synthesis.

5. The objective of IGBP is to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occurring in this system and the manner in which they are influenced by human activities.

6. This overall aim encompasses a wide spectrum of research activities. To provide coherence, efforts are focused on the processes that affect global change on a decade-to-century time-scale, on those that are most susceptible to human perturbations and on those that will most likely lead to a practical, predictive capability. Emphasis on those features helped in the identification of initial priorities within the Programme and in the setting of realistic goals. The results of IGBP research are of very great importance to the Intergovernmental Panel on Climate Change (IPCC), thus providing scientific justification to the political process, for example, through the Framework Convention on Climate Change (FCCC) following the United Nations Conference on Environment and Development (UNCED), which was held from 3 to 14 June 1992 at Rio de Janeiro, Brazil.

7. The space technologies of interest to IGBP are primarily Earth observation technologies, including remote sensing of the environment and natural resources, and meteorological and climatic observations of the surface and atmosphere. Communications satellites, broadcasting satellites, navigation satellites and other space systems can also contribute in more indirect ways to the goals of IGBP. Compared with ground surveys, satellite observations provide less detail, but are more economical, particularly where repetitive monitoring is required. Large-scale phenomena or patterns that are not visible to a ground observer can often be seen on satellite images, and transboundary phenomena that can be logistically difficult to survey from the ground or air offer no difficulty for space observations. Environmental changes that occur gradually over periods of years or decades can be measured from the satellite data regularly acquired by the same sensors under the same conditions. Transient atmospheric or oceanographic phenomena can be followed by daily or hourly observations by meteorological or dedicated oceanographic satellites. Data obtained by space-borne instruments should be an integral part of the whole picture, composed of information gathered from all possible sources.

8. Three fifths of the land area and nearly all of the rich and varied tropical regions of the globe, which are also the repository of the bulk of global genetic diversity, are occupied by developing countries. They have the privilege and responsibility to study and understand this global environment scientifically. The applications and benefits from such an understanding are immediate and immeasurable.

9. The initial task of IGBP was to define critical gaps in the understanding of global biogeochemical cycles and life support processes, in order to focus future research efforts. Further review and planning carried out by the international scientific community resulted in the formulation of six key research questions which are described briefly in the present study. Each question is now addressed by an established Core Project, with an operational duration of approximately 10 years.

10. Throughout the development of IGBP, there has always been close collaboration with other relevant ICSU activities and with its two companion global change programmes, the World Climate Research Programme (WCRP) - organized jointly by ICSU, the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) - and the Human Dimensions Programme (HDP), organized by the International Social Sciences Council. These programmes are directed at physical and societal aspects of global change, respectively, and complement many areas of IGBP research. The three programmes together comprise the main international global change research effort now in operation. Many formal and informal links have been developed between these programmes and various bodies.

11. A three-category classification scheme of IGBP research has been developed and recommended by the Scientific Steering Committee (SSC) of IGBP to facilitate the process of definition and recognition of its component studies. The three categories and their main characteristics are: core research, which directly addresses the Science Plan goals of IGBP projects, is part of their formal structure and is coordinated by the relevant SSC; regional/national research, which is closely linked to Science Plan objectives (but may have

other overall aims), and is coordinated at a national or regional level; and relevant research, which makes an indirect contribution to the project, without formal affiliation.

12. Since the purpose of IGBP research is to provide new knowledge, it is unrealistic to try to forecast in detail the specific scientific products of the programme in five years. Nevertheless, it is possible, and desirable, to set goals and to define deliverable milestones against which progress can be assessed. While the precise outcome of the research is unpredictable, those responsible for funding the research need to know what general insights can be expected if support is provided at the level considered necessary for the implementation of the core projects' science plans.

13. All IGBP core projects will contribute individually to understanding important global change processes, and hence to model-based predictions of the behaviour of key features of the Earth system. Collectively, their potential is greatly enhanced as models can be constrained by the mass continuity in biogeochemical cycles and energy balances. However, additional problems are introduced as a result of the greatly increased complexity of the fully global approach as well as with simplifications needed in any attempt to dynamically link sub-component models. Therefore, it is not the aim of IGBP to produce a single, all-embracing global model that includes all known interactions between the very large number of biological, chemical and physical processes operating over the full spectrum of time and space scales. Instead, a suite of models, of varying complexity and realism, are being developed and employed to attack specific questions. This approach enables the predictive characteristics of the models to be tested against a variety of data sets, especially those generated for that purpose by the core projects.

14. IGBP research is not primarily directed towards the development of mitigation responses to counteract natural and man-made environmental change. Such work is more appropriate to engineers and agriculturalists, among others. Nevertheless, the results of IGBP will undoubtedly play a significant role in the assessment of mitigation strategies by providing the scientific underpinning that is needed, both for deciding whether a particular strategy is likely to be successful or not, and for evaluating its wider environmental consequences.

15. Comprehensive global observations are essential complements to the research programmes designed to improve our understanding of the Earth system. Such measurement systems will provide the means to monitor and detect the many facets of global change, and will provide the global data sets of long duration necessary for model calibration, validation and further development. Current operational observation systems (e.g. the World Weather Watch and Global Atmosphere Watch systems) do not fully meet this need because they were designed for more limited purposes.

16. Three closely linked global observational systems have been proposed to provide integrated, multiscale monitoring of global change: Global Climate Observing System (GCOS), Global Ocean Observing System (GOOS) and Global Terrestrial Observing System (GTOS). The concept and scope of these systems are currently being formulated by ICSU in partnership with WMO, the United Nations Environment Programme (UNEP) and IOC of UNESCO, and the Food and Agriculture Organization of the United Nations (FAO). Since all three systems are primarily building on existing operational and research activities, their operational nature distinguishes them from the research programmes. However, IGBP must play a significant role in developing their scientific specifications and strategy-for-use and contributing to calibration, validation and other aspects of quality control.

17. Each of the global observation systems will need to develop procedures for efficient data management. IGBP is assisting in that exercise to ensure that the data sets help meet the needs of, and are accessible to, the research community. For satellite data, there are already close working links between the IGBP Data and Information System (IGBP-DIS) and the Committee for Earth Observation Satellites (CEOS) with which

IGBP has affiliate status. These links will be further developed, thereby assisting in the identification, prioritization and use of environmental data sets relevant to global change research. In addition, the regional collaboration through the IGBP System for Analysis, Research and Training (START) will provide a mechanism for both compilation of existing data and a structure for continuous monitoring of key variables.

18. The CEOS/IGBP-DIS Pilot Project was initiated at the sixth plenary meeting of CEOS in London in December 1992. Its objective is to assess the applicability of data exchange principles in support of global change research. One of the principles adopted at the plenary was that non-discriminatory access to satellite data by all users for global change, climate and environmental research and monitoring is essential. This should be achieved within the framework of the exchange and sharing mechanisms set up by CEOS members. CEOS invited IGBP-DIS to propose a pilot project for data use by IGBP Core Projects, in which the applicability of this principle would be tested for exchange of high resolution data. The project also involves commercial considerations, especially in relation to data from Landsat, SPOT, the European Remote Sensing (ERS) satellite and the Japanese Earth Resources Satellite (JERS).

19. Plans for a full suite of satellite-borne sensors in the late 1990s, specifically designed for environmental mapping and monitoring, are crucial to the success of IGBP. Yet there is also the potential for wider application of remote sensing systems that are already in operation, particularly the meteorological satellites operated by the United States National Oceanographic and Atmospheric Administration (NOAA). Although not originally intended for studies of global vegetation, the Advanced Very-High Resolution Radiometer (AVHRR) sensor carried on the NOAA satellites detects radiation separately in the red and infrared parts of the spectrum. The red spectral measurements are sensitive to the chlorophyll content of vegetation, and the near infrared to the mesophile structure of leaves. Taken together they provide information on a wide variety of important attributes of vegetation cover, including leaf area index, leaf biomass, net primary productivity and photosynthetic capacity. Methods are also being developed to use AVHRR data to determine land-surface temperature, the extent and frequency of biomass burning (forest and grassland fires) and evaporation-transpiration rates.

20. Practical and financial difficulties in gaining access to satellite data for environmental purposes have been a factor limiting the use of satellite data in many countries, particularly the developing countries. Member States of COPUOS have frequently expressed their concern over such high prices. Some actions have been taken to develop flexible pricing arrangements, including lower prices for research use, educational use and archival data.

21. Each year during the session of the Committee and its Scientific and Technical Subcommittee, Member States and particularly developing countries discuss the problems related to non-restricted and non-expensive access to space-related information. To facilitate this process, the existing nucleus of the International Space Information Service (ISIS) within the United Nations Office for Outer Space Affairs (OOSA) can be substantially expanded in cooperation with, and with the support of, other organizations. Possible next steps in this expansion process could include:

(a) Compilation of a list of activities and programmes conducted by different national and/or international organizations and agencies to provide a basis for better coordination;

(b) Development of a database where data from different Earth observation systems can be obtained in order to facilitate the availability of data for countries with little or no space research activity and, in particular, developing countries;

(c) Development of a database which will contain information for decision makers;

(d) Investigation of the role which the proposed regional centres for space science and technology education could play in disseminating and coordinating the compilation of Earth observation data;

(e) Development of databases with information on other space-related subjects, including space communication, meteorology, navigation and basic space science.

22. The further development of ISIS will provide all interested parties with direct access through the Internet to all information sources available. ISIS will also facilitate the organization of and search for space-related information on behalf of Member States and will provide advice on how such information can best be utilized.

23. In an effort to provide increased opportunities for advanced education to people from the developing countries, the United Nations, through OOSA, has begun an initiative to establish Centres for Space Science and Technology Education in each region covered by the regional commissions of the United Nations. The emphasis of the centres on educating educators will provide multiplier effect to ensure a long-term, adequate supply of trained specialists in the various disciplines required for sustainable development and environmental monitoring.

24. In the initial phase the centres will concentrate on providing an advanced education, research and applications development programme in remote sensing, satellite meteorology and geographic information systems. Improving data processing and information management capabilities in developing countries including archives of satellite data and links to international environmental databases, such as the UNEP Global Resource Information Database (GRID), will be an important element of the centres' functions. The centres will therefore make a major contribution to meeting the need (as identified in Agenda 21[2] of UNCED) to develop the capacities of developing countries to participate effectively in the global effort to protect the environment and ensure the sustainable development of all countries.

25. In the area of Earth observation systems, for example, the programme of each regional centre will:

(a) Develop skills and knowledge of university educators, environmental research scientists and project personnel in remote sensing and related technologies for subsequent application in national development and environmental management programmes;

(b) Assist educators in the development of environmental and atmospheric sciences curricula that they can use to advance the knowledge of their students in their own institutions/countries;

(c) Develop the skills of environmental research scientists and project personnel in the design, development and application of remote sensing techniques in natural resources management and biodiversity protection;

(d) Assist research scientists and project personnel in preparing space-derived information for presentation to policy and decision makers in charge of national and regional development programmes;

(e) Enhance regional and international cooperation in space science and technology programmes, particularly those that are related to environmental monitoring and natural resources management, and support and contribute to the work of institutions of higher education in each region and the activities of national/regional remote sensing user assistance and training centres;

(f) Assist in disseminating to the general public the value of space science and technology in improving their everyday quality of life.

26. The programmes will focus on teaching techniques and methods in environmental information systems as applied to educational, environmental and economic development issues. Case-studies using remote sensing and meteorological satellite data that can be processed, analysed and stored on micro-computer systems will be prepared in advance to provide hands-on illustrations of applications to specific natural resource surveys and to specific environmental monitoring and assessment exercises.

27. An integral part of each of these centres for space science and technology education will be a data management unit. Through this unit, each centre will have direct linkages with existing relevant global data centres and the nearest UNEP/GRID centres. Such linkages will enable those participating in the programmes of these centres to utilize the data in the archives of the data centres, particularly when they undertake projects that can benefit from their gaining such an access. Each centre will have direct access to the ESA Mercure satellite-based communications network proposed by European industry and European Space Agency (ESA) for the benefit of the United Nations and UNEP. The Mercure network would provide a modern, state-of-the-art global communication capability for the transfer of environmental data between different UNEP/GRID centres and between databases and archives and users of environmental data.

28. Each of these regional centres will be established in a major national science and technology-oriented university or research institution. Such an arrangement will enable the centres to optimally utilize the existing professional staff and physical infrastructure at the host institution. The participants in the programmes of the centres will also be able to collaborate with the graduates of existing training and user assistance centres on major research and application projects for the benefit of their countries. The establishment of the regional centres will require a strong commitment of support from the host countries as well as technical and financial assistance from developed countries and international organizations. Such assistance could take the form of full- or part-time technical specialists, data processing equipment and software, satellite data, funding for scholarships and other human, technical and financial resources.

29. The importance of the IGBP initiative and its achievements to date have been widely acknowledged and formally recognized at both the governmental and intergovernmental level. Its main work phase, with all established core projects operational, is just beginning. However, existing support is inadequate for full implementation. For that to be achieved, there must now be a long-term commitment to support both the research and its international infrastructure. The lack of funding for either component would seriously jeopardize the success of the programme.

30. Recognizing that developing countries are most vulnerable to the impact of global changes both in terms of economics and human welfare, and recognizing that IGBP provides a unique opportunity for developing countries to build an expert and self-reliant capacity in the interdisciplinary field of basic sciences for environment and development, all developing countries are encouraged to join IGBP and participate in it. There must be a national commitment to the programme and at least modest resources made available to their scientists. It is, however, the responsibility of scientists from developing countries to make decision makers in their own countries aware of the benefits that can be derived from the support of IGBP activities and that such support is in the overall national interest.

31. To facilitate the process of increasing the participation of developing countries in the IGBP programme, as well as in other programmes and projects involving space research and applications, COPUOS and its subsidiary bodies should make specific recommendations, based on their deliberations. COPUOS may wish, for example, to recommend the expansion of ISIS within the Secretariat to better serve the need for coordinating and expediting access to environmental databases and other sources of information. Similarly, the role of the proposed centres for space science and technology education in assisting IGBP activities of developing countries should be explored in more detail.

Notes

[1]Official Records of the General Assembly, Forty-ninth Session, Supplement No. 20 (A/49/20), para. 29.

[2]Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992 (United Nations publication, Sales No. E.93.I.8 and corrigenda), vol. I: Resolutions Adopted by the Conference, resolution 1, annex II.

Annex

GLOBAL CHANGE: PARTICIPATION OF DEVELOPING COUNTRIES AND POSSIBILITIES OF ENHANCING IT

Study by the Secretariat*

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*The present study has not been formally edited.

INTRODUCTION

1. For Earth system research – the study of global-scale interactions that determine the habitability of our planet – national and international collaboration between regional research groups should be extended all over the globe. It is apparent that no single unit or organization can accomplish this alone. There are three main reasons for this. First, such research encompasses many different disciplines, such as atmospheric chemistry and physics, oceanography, geology, terrestrial ecology, soil science, hydrology, and social science. The need for new working links among practitioners of these disciplines, and the pooling of intellectual resources, transcends the existing structures for scientific contacts, based on those traditional fields. Secondly, no single group can collect the many data sets that are needed for global scale analyses and agreement must be reached on sharing responsibilities for studies at different locations, and, as far as possible, common methodologies must be developed to ensure the compatibility of results. Thirdly, there is an urgency to such work, set by the political implications of increasing environmental degradation and concern for sustainable development. Ecologically and economically significant changes in soil, water and air quality have already occurred on a global scale. With an increasing human population, these are bound to be accentuated. Changes in climate occur, now not only as a result of natural variability but probably also because of human-induced changes in the composition of the atmosphere.

2. The International Geosphere-Biosphere Programme (IGBP): A Study of Global Change, was established in 1986 by the International Council of Scientific Unions (ICSU) to address these challenges of global change, recognizing that the complexity and importance of this topic required an international approach, with an emphasis on a soundly-based framework for research planning, implementation and synthesis.

3. The objective of IGBP is: "To describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human activities."

4. This overall aim encompasses a very wide spectrum of research activities. To provide coherence, effort is focused on the processes that affect global change on the decade to century time-scale, on those that are most susceptible to human perturbations, and on those that will most likely lead to a practical, predictive capability. Emphasis on those features helped in the identification of initial priorities within the programme, and in the setting of realistic goals. The results of IGBP research are of very great importance to the Intergovernmental Panel on Climate Change (IPCC), thus providing scientific justification to the political process, for example, through the Framework Convention on Climate Change (FCCC) following the United Nations Conference on Environment and Development (UNCED) which was held from 3 to 14 June 1992 at Rio de Janeiro, Brazil.

5. The space technologies of interest to the IGBP are primarily Earth observation technologies, including remote sensing of the environment and natural resources and meteorological and climatic observations of the surface and atmosphere. Communications satellites, broadcasting satellites, navigation satellites, and other space systems can also contribute in more indirect ways to the goals of IGBP. Compared with ground surveys, satellite observations provide less detail, but are much more economical, particularly where repetitive monitoring is required. Large-scale phenomena or patterns that are not visible to a ground observer can often be seen on satellite images and trans-boundary phenomena that can be logistically difficult to survey from the ground or air offer no difficulty for space observations. Environmental changes that occur gradually over periods of years or decades can be measured from the satellite data regularly acquired by the same sensors under the same conditions. Transient atmospheric or oceanographic phenomena can be followed by daily or hourly observations by meteorological or dedicated oceanographic satellites. Of course, data obtained by space-borne instruments should be an integral part of the whole picture, composed of information gathered from all possible sources.

I. THE AIMS OF THE GLOBAL CHANGE PROGRAMME

A. Structure of the programme

6. The initial task of the IGBP was to define critical gaps in the understanding of global biogeochemical cycles and life support processes, in order to focus future research efforts. The initial priorities were outlined in IGBP Report No. 4 (1988). Further review and planning carried out by the international scientific community resulted in the formulation of six key research questions (IGBP Report No. 12, 1990); each is now addressed by an established Core Project, with an operational duration of approximately ten years. The Core Projects and the priority issues to be addressed by each project are described below:

a) How is the chemistry of the global atmosphere regulated, and what is the role of biological processes in producing and consuming trace gases? (International Global Atmospheric Chemistry project, IGAC). Priority issues: chemical transformations, biospheric sources and sinks (marine and terrestrial) of atmospheric constituents that have a role in controlling the global system, especially radioactive trace gases, aerosols and reactive radicals.

b) How will global changes affect terrestrial ecosystems? (Global Change and Terrestrial Ecosystems, GCTE). Priority issues: responses of natural and managed ecosystems to changes in climate, atmospheric composition and land use, with emphasis on both impact and feedback processes. These will be investigated experimentally and through the development of dynamic vegetation models and by examining the role of ecological complexity in the functioning of the global system.

c) How does vegetation interact with the physical processes of the hydrological cycle? (Biospheric Aspects of the Hydrological Cycle, BAHC). Priority issues: the effect of land surface properties (soil, vegetation and topography) on water, carbon and energy fluxes; temporal and spatial integration of those processes, including improved modelling of complex landscapes; and the down-scaling of climate information obtained from general circulation models.

d) How will changes in land use, sea-level rise and climate alter coastal ecosystems, and what are the wider consequences? (Land-Ocean Interactions in the Coastal Zone, LOICZ). Priority issues: the effects of changes in external forcing on coastal fluxes; coastal biogeomorphology and sea level rise; carbon fluxes and trace gas emissions; and the economic and social impact of global change on coastal systems.

e) How do ocean biogeochemical processes influence and respond to climate change? (Joint Global Ocean Flux Study, JGOFS). Priority issues: processes controlling the fluxes of carbon and associated biogenic elements within the ocean, and their exchanges with the atmosphere, sea floor and continental boundaries; interpretation and application of remotely-sensed ocean colour data.

f) What significant climatic and environmental changes occurred in the past, and what were their causes? (Past Global Changes, PAGES). Priority issues: high resolution reconstruction, at the global scale, of the changes occurring in the past 2,000 years; investigations of the more radical re-organizations of the global system during the most recent glacial/interglacial cycles.

7. Two other Core Projects are being developed for possible acceptance: Land Use/Cover Change (LUCC), and, in an early planning stage, the Global Ocean Euphotic Zone Study (GOEZS). (IGBP Report No. 28, 1994). In addition, three activities of an over-arching and integrative nature are now operational:

a) A Task Force on Global Analysis, Interpretation and Modelling (GAIM), responsible for promoting the development, evaluation and application of comprehensive prognostic models of the global biogeochemical system, and subsequently linking such models to those of the physical climate system.

b) The IGBP Data and Information System (IGBP-DIS), used to assist Core Projects in meeting their data acquisition and data management needs; as well as to facilitate collaboration with the space agencies, other data-producing bodies, and international data centres.

c) The Global Change System for Analysis, Research and Training (START), used to promote regional capacity building in global change science, and the establishment of networks for regionally-based research and analysis relevant to the origins and impact of global environmental change.

B. Relations with other programmes

8. Throughout the development of IGBP, there has always been close collaboration with other relevant ICSU activities and with its two companion global change programmes, the World Climate Research Programme (WCRP, organized jointly by ICSU, the World Meteorological Organization [WMO] and the Intergovernmental Oceanographic Commission [IOC] of the United Nations Educational, Scientific and Cultural Organization [UNESCO]) and the Human Dimensions Programme (HDP, organized by the International Social Sciences Council). These programmes are directed at the physical and societal aspects of global change, respectively, and complement IGBP research in many areas. The three programmes together comprise the main international global change research effort now in operation. Many formal and informal links have been developed between these programmes and other bodies. For example, START is jointly sponsored by all three programmes; LUCC is a joint initiative of IGBP and HDP. In addition to providing support for IGBP, JGOFS is co-sponsored by the Scientific Committee on Oceanic Research (SCOR) and IGAC is co-sponsored by the International Commission on Atmospheric Chemistry and Global Pollution (ICACGP), both of which are ICSU bodies. BAHC is strongly linked to WCRP's Global Energy and Water Cycle Experiment (GEWEX) project. The initial planning of the GOEZS effort is being co-sponsored by IGBP, SCOR and WCRP.

9. A joint WCRP-IGBP working group will coordinate the planning of large-scale field experiments that are of interest to GEWEX, BAHC, GCTE and IGAC. Four components have been accepted for further development within the WCRP: 1) the role of the stratosphere in the climate system; 2) the study of ozone depletion and related chemical processes in the upper atmosphere; 3) the monitoring of global change occurring in the stratosphere; and 4) the modelling and monitoring of UV-B penetration throughout the atmosphere. Such studies should provide the basis for a new WCRP project called "Stratospheric Processes and their role in Climate" (SPARC). GCTE and JGOFS will assist in developing links between SPARC and research groups considering of the biological effects of UV-B flux.

10. There are some fundamental differences in the working methods between social scientists and natural scientists. In dealing with environmental change, however, it is essential that these groups work together. Some work has already been undertaken, and some problems have been identified. Data are of considerable concern. Most social science data are collected according to political boundaries, that usually do not coincide with the ecological boundaries that are most suitable for the work of natural scientists. There are even important uncertainties with respect to what should be fully comparable factual data. For example, in a case study of deforestation in Brazil, it was pointed out that estimates of the current deforestation rate differed significantly. An analysis of Landsat images of the area performed at the University of New Hampshire (United States), revealed that the deforestation might be very dendritic (even fractal) in nature, and that the apparent amount depends upon the scale at which it is examined.

C. Components of the IGBP organizational structure

11. The Scientific Committee for the IGBP (SC-IGBP) consists of members appointed by ICSU, plus all Chairs of IGBP Scientific Steering Committees, Standing Committees and Task Forces. The Chairs of the WCRP Joint Scientific Committee and the HDP Committee also serve on the SC-IGBP as *ex officio* members,

together with a representative of the ICSU Advisory Committee on the Environment (ACE). The SC-IGBP was initially established in 1990 to follow-up on the work of the Special Committee for the IGBP. The responsibilities of the SC-IGBP are to develop a prioritized programme, guide its implementation and publicize its results. The SC-IGBP ensures overall integration within the programme, administers the central budget, develops collaborative links with WCRP and HDP, and serves as its liaison with ICSU and other organizations.

12. The IGBP Secretariat is responsible for carrying out the decisions of the Scientific Committee. It serves as the focus for planning and coordination, assisting the work on the Core Projects and ensuring the development of a common IGBP philosophy, which is necessary for the programme-wide integration of results. It is also responsible for publishing IGBP Reports, the Global Change Newsletter and other central publications. The Secretariat is located at the Royal Swedish Academy of Sciences in Stockholm.

13. The detailed planning and implementation of each Core Project is directed by a Scientific Steering Committee (SSC), appointed by the SC-IGBP. In addition, Standing Committees have been established for IGBP-DIS and START, and GAIM is led by a Task Force. Core Project Offices have been established to assist the SSG and SCs with their international communication and coordination responsibilities.

14. The IGBP Scientific Advisory Council (SAC) provides advice on the scientific content of the programme, assesses its results and makes recommendations on the general policies of the SC. It meets every 2-3 years and is composed of representatives of National IGBP Committees (NC) and liaison persons with other ICSU scientific members, under the Chairmanship of the ICSU President. Representatives of other organizations involved in global change research also attend.

15. The IGBP NCs also provide the formal interface between researchers in participating countries and the international structure. They are expected to assist with national planning and coordination; to contribute to the conceptual and practical development of IGBP as a whole; and to arrange the payment of national contributions towards the central costs of the programme. As of December 1993 there were 69 National Committees.

D. Categories of IGBP research

16. A three-category classification scheme of IGBP research has been developed and recommended by the Scientific Steering Committee of IGBP to facilitate the process of definition and recognition of its component studies. The three categories and their main characteristics are: Core Research which directly addresses the Science Plan goals of IGBP projects as part of their formal structure and coordinated by the relevant SSC; Regional/National Research which is closely linked to Science Plan objectives (but may have other overall aims), and is coordinated at a national or regional level; and Relevant Research which makes an indirect contribution to the project, without formal affiliation. Further details of this classification system are provided below:

a) Core Research Projects: These can be initiated directly by the SSC, adopted by the SSC, or be national or regional projects that have been accepted by the SSC on the basis that they provide components, which, when combined with projects from other national IGBP programmes, form a large-scale, internationally integrated research project. These projects are eligible for assistance in obtaining funds from national and international agencies. They will maintain close communication with the relevant Core Project Office.

b) Regional/National Research Projects: These projects arise from national IGBP committees or other national and regional groups of research organizations. Although not part of a Core Research Programme, they are an important part of the overall effort because they provide a critical link between

global scale Core Research and the national and regional scales which are of concern to individual countries and regions.

c) Relevant Research Projects: These are smaller projects initiated by individual investigators or institutions. They accumulate data through case studies and site-specific research and thus provide input to the broad knowledge that supports the overall effort. Some of these projects may be potential parts of a Core Research Programme, but are first considered by the appropriate national IGBP committee before being submitted to an SSC.

17. Even with these criteria, the classification of national projects may not always be clear-cut. Furthermore, the category allocation of a research activity may change according to its own development and the evolving priorities of the IGBP Core Projects. Since such changes are unavoidable, it should be noted that the categories are not based on scientific merit *per se*; but rather relate to research objectives, implementation procedures, and practical problems of dividing coordination responsibilities between the different levels of the Core Project structure. Core Research is expected to be of very high scientific quality though work of equally high scientific importance can also be found in the other categories.

18. For this conceptual structure to be functionally useful, the Core Project SSCs must be kept fully informed about all IGBP research being planned and carried out in their specific subject areas, and decide on what should be considered Core Research. In addition, the NCs must be aware of research at the regional/national level (with the involvement of regional START Committees, where appropriate).

E. Evaluating the progress of IGBP

19. The objectives and priorities of IGBP imply programmatic responsibilities relating to the assessment of global environmental change. Each Core Project is responsible for an ongoing assessment of scientific understanding in its field. In addition, GAIM is responsible for providing collective oversight within the programme and carrying out integrative studies. The output from these various assessment activities will be published.

20. With plans underway for a classification and summary of Core Project research for the IGFA Resource Assessment, information on the institutional resources will become available for each Core Project. In an effort to provide additional information to IGBP reviewers, IGAC has initiated plans for a bibliography or database of papers which have been produced as a result of IGAC research. It is realized that prompt publication of the scientific results of the IGBP in refereed international journals is essential, with due acknowledgement given that the work was performed as part of the IGBP. DIS is making plans for an IGBP Internet interface to provide general information about IGBP, and START is evaluating ways to connect areas which are not currently linked to Internet.

21. In addition to the internal mechanisms for progress assessment, the SC-IGBP has developed plans for an external evaluation of the programme to be conducted in 1994 and 1995, in cooperation with ICSU and IGFA. The evaluation will provide an independent assessment of the scientific results and the overall effectiveness of the programme. The review will be essential for an internal re-assessment by the SC-IGBP of its priorities and modes of action. It should also provide a solid basis for ensuring continued and adequate financial support for both the research projects and coordination functions.

22. Many IGBP scientists are also closely involved in the Science and Impacts Assessments of the IPCC. The IPCC is the body responsible for the scientific and technical assessment underlying the Framework Convention for Climate Change agreed upon at UNCED in June 1992. The IPCC was originally created in 1988 by the United Nations Environment Programme (UNEP) and the WMO. It is financed partly by these organizations and partly by voluntary contributions from various countries. IPCC is a reviewing, and not a

research body, and is therefore highly dependent on in-depth inputs from international programmes – particularly WCRP and IGBP. For the 1994 IPCC Report on Radiative Forcing of Climate (Working Group 1), IGBP researchers are contributing to reviews of the scientific research results on the carbon cycle, other trace gases and atmospheric chemistry, aerosols, radiative forcing, and the relative importance of emissions of different greenhouse gases.

23. The 1995 IPCC Scientific Assessment will be based on this material, with additional coverage of climate processes; observed climate variability and change; model predictions and validations; sea level rise; biotic responses to climate change and feedbacks to climate; and reducing uncertainties. IGBP scientists will contribute to most of these chapters and IGBP and WCRP, through their chairmen, will be jointly responsible for the final chapter in the Working Group 1 assessment, addressing the need for further research to reduce the uncertainties. While the 1990 IPCC Scientific Assessment strongly emphasized the physical components of the climate system, the 1995 Assessment provides for greater attention to be given to biospheric control of the atmospheric composition, feedback interactions with marine and terrestrial ecosystems, and the insights provided by palaeoclimate studies.

F. Expected outputs of the programme

24. Because the purpose of IGBP research is to provide new knowledge, it is unrealistic to try to forecast in detail the specific scientific products of the programme in five years. Nevertheless, it is possible – and desirable – to set goals, and define deliverable milestones, against which progress can be assessed. While the precise outcome of the research is unpredictable, those responsible for funding the research need to know what general insights can be expected if support is provided at the level considered necessary for the implementation of the Core Project science plans.

25. All IGBP Core Projects will contribute individually to our understanding of important global change processes, and hence to model-based predictions of the behaviour of key features of the Earth system. Collectively, their potential is greatly enhanced as models can be constrained by the mass continuity in biogeochemical cycles and energy balance. However, additional problems are introduced as a result of the greatly increased complexity of the fully-global approach, as well as simplifications needed in any attempt to dynamically link sub-component models. Therefore, it is not the aim of IGBP to produce a single, all-embracing global model that includes all known interactions between the very large number of biological, chemical and physical processes operating over the full spectrum of time and space scales. Instead, a suite of models, with varying complexity and realism, is being developed and employed, to attack specific questions. This approach enables the predictive characteristics of the models to be tested, against a variety of data sets, especially those generated for that purpose by the Core Projects.

26. IGBP research is not primarily directed towards the development of mitigation responses to counteract natural and man-made environmental change. Such work is more appropriate to engineers and agriculturalists, among others. Nevertheless, the results of IGBP will undoubtedly play a significant role in the assessment of mitigation strategies by providing the scientific underpinning that is needed, both for deciding whether a particular strategy is likely to be successful or not, and for evaluating its wider environmental consequences.

27. Thus IGBP studies (potential or already ongoing) may assist in evaluating various proposals for mitigation and/or amelioration strategies such as the disposal of fossil fuel CO_2 in the oceans; the enhancement of oceanic uptake of CO_2 via iron fertilization; the addition of chemicals to the upper atmosphere to reduce ozone depletion; the control of coastal erosion and the movement of littoral sediments arising from sea level rise and coastal subsidence; the diversion of rivers and creation of large freshwater reservoirs for climate control and water supply purposes; the sequestration of additional CO_2 by reforestation and afforestation; and the decrease of methane emissions from rice paddies by changing cultivation practices.

28. However, in most, if not all of these examples, the current understanding of the basic science involved can only provide a very crude estimate of the likely effectiveness and environmental consequences of the proposed action. In some cases it is arguable whether any of the anticipated benefits will be realized, while at the same time, many unknown risks of undesirable "side effects" remain. As scientific understanding improves in the next five years, it is hoped that IGBP will increasingly be able to provide the knowledge base on which the environmental (and economic) costs and benefits of such proposals can be assessed.

29. For at least the next 10-20 years, land-use change is likely to continue to be much more important than climate change in altering the global environment. The IGBP's proposed LUCC project, expected to be operational by 1995, will focus attention on those human activities that directly affect attributes of land cover, and their underlying driving forces (population, level of affluence, technology, political economy, political structure, and attitudes and values). Models will be developed to investigate the role of these factors in a variety of different environmental, historical and social contexts and their implications for biogeochemistry, ecological complexity and other aspects of global change. Close cooperation will take place among GCTE (with regard to its functional classification of vegetation types, and interests in global change impacts on agriculture and forestry); LOICZ (with regard to the effect of different land-use patterns on catchment basin dynamics and delivery, and changes of land use/cover in the coastal zone); and with PAGES (with regard to the possible role of pre-industrial land use changes on regional and global climate).

II. THE ROLE OF SPACE TECHNOLOGIES IN IGBP

A. The role of space technologies in global observing systems

30. Comprehensive global observations are essential complements to the research programmes designed to improve our understanding of the Earth system. Such measurement systems will provide the means to monitor and detect the many facets of global change, and provide the global data sets of long duration necessary for model calibration, validation and further development. Current operational observation systems (e.g., the World Weather Watch and Global Atmosphere Watch) do not fully meet this need, since they were designed for more limited purposes.

31. Three closely-linked global observational systems have been proposed to provide integrated, multi-scale monitoring of global change: the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), and the Global Terrestrial Observing System (GTOS). The concept and scope of these systems are currently being formulated by ICSU in partnership with WMO, UNEP, and UNESCO's IOC and the Food and Agriculture Organization (FAO). Because all three systems are building primarily on existing operational and research activities, their operational nature distinguishes them from the research programmes. However, IGBP must play a significant role in developing their scientific specifications and strategy-for-use, and contributing to calibration, validation and other aspects of quality control. Examples of relevant actions include:

a) GCTE assistance to GTOS in defining core measurements and field sites, with the latter covering both natural and managed habitats over a wide range of climatic regimes;

b) involvement in algorithm development for remote-sensing satellite data treatment;

c) the assembly of experimental global data sets (such as the IGBP-DIS 1 km Advanced Very High Resolution Radiometer (AVHRR) data set, to become part of the shared land surface component of GCOS and GTOS); and

d) the provision of advice regarding appropriate chemical, biological and optical measurements within the oceanic component of GCOS and the climate module of GOOS, based on techniques developed through JGOFS, particularly its time series studies.

32. Each of the global observation systems will need to develop procedures for efficient data management. IGBP is assisting in that exercise, to ensure that the data sets help to meet the needs of, and are accessible to, the research community. For satellite data, there are already close working links between IGBP-DIS and the Committee for Earth Observation Satellites (CEOS) with which IGBP has Affiliate status. These links will be further developed, thereby assisting in the identification, prioritization and use of environmental data sets relevant to global change research. In addition, the regional collaboration through START will provide a mechanism for both compilation of existing data and a structure for continuous monitoring of key variables.

B. CEOS/IGBP-DIS Pilot Project

33. The CEOS/IGBP-DIS Pilot Project was initiated at the Sixth Plenary of CEOS in London in December 1992. Its objective is to assess the applicability of data exchange principles in support of global change research. One of the principles adopted at the plenary was that "non-discriminatory access to satellite data by all users for global change, climate and environmental research and monitoring is essential. This should be achieved within the framework of the exchange and sharing mechanisms set up by CEOS members". CEOS invited IGBP-DIS to propose a pilot project for data use by IGBP Core Projects, in which the applicability of this principle would be tested for exchange of high resolution data. The project also involves commercial considerations, especially in relation to data from Landsat, the French System Probatoire dÓbservation de la Terre (SPOT) satellite, the European Remote Sensing satellite (ERS-1) and the Japanese Earth Resources Satellite (JERS). The project has now been extended to include data from the Indian Remote Sensing satellite (IRS-1) and its specific objectives are:

a) to ascertain what data are available from existing high spatial resolution satellite systems for global change research projects within IGBP;

b) to assemble databases from existing archives for selected IGBP Core Projects;

c) to develop and implement a data acquisition model for acquiring new high resolution data sets to support selected IGBP Core Projects; and

d) to provide the global change research community with ready access to these data at the marginal cost of reproduction.

34. The use of high-resolution data will be critical in answering the following questions for carbon cycle research: 1) What is the rate of deforestation in the tropics? 2) How much formerly forested land is in secondary succession? and 3) How much deforested land is abandoned each year?

35. A type of study carried out by IGBP requiring high-resolution data is one conducted along a transect of 1000 kms or more of a varying climate and/or ecosystem. For example, the North Australian Tropical Transect (NATT) is a research programme, extending from Darwin to Alice Springs, whose objectives are to determine the effects of soil and climatic variability, land management and global climate change on the savannahs of northern Australia. NATT takes advantage of the gradient of decreasing mean annual rainfall with increasing distance from the northern coast of the Northern Territory. A similar transect study is being conducted in West Africa. By comparing the results obtained from the two studies, the effects of vastly different human pressures will be seen.

36. Studies to be undertaken within the NATT programme include determination of land degradation within Australian tropical savannahs, emissions of trace gases during fires, effects of land management on the water cycle, and the development of cooperative programmes with local land care groups and, where appropriate, with state and federal agencies. The highest priority data requirement for this project will be to obtain recent data sequences (over the last two years) across the transect using Landsat or SPOT Imagery. It will also be important to have a long-term data archive (covering approximately 20 years) over several sites to assist in time sequence analysis of ecosystem change. A combination of Landsat and SPOT measurements will allow analysis of the functional characteristics of vegetation cover.

37. The BAHC programme of IGBP studies vegetation-water interaction on regional scales. This involves modelling of the water and energy balance, scaling algorithms, measurements of vegetation-water interaction, and surface fluxes. To this end, simultaneous satellite measurements are being conducted over several sites in Europe, North Africa, the United States, Russia and China. The areas investigated are the size of a SPOT scene (60x60 km), and their study usually covers five months of a year starting with the "green-up" phase and going to the "dry-down" conditions of vegetation. Frequent coverage of the area by high-resolution images are the highest priority requirements for this project. The overall requirements for the CEOS/IGBP-DIS pilot project concerned two transects (Australia and West Africa), the tropical forests in Africa and South America, and several smaller sites in European coastal areas (the Mediterranean and the Baltic), and an inland site in China. The total estimate of data required is of the order of 100 scenes per year of SPOT multispectral, 50 per year of SPOT-panchromatic, 300 per year of MOS and about 200 per year from the Landsat-thematic mapper.

38. The replies from the space agencies were positive and encouraging. The proposed availability of selected global change researchers up to 400 thematic mapper scenes per year at the "copying" price of $240 per scene. The National Space Agency of Japan (NASDA) reported the availability of approximately 300 scenes per year of MOS-Multispectral Electronic Self-Scanning Radiometer data over East and Southeast Asia, which could be purchased at the cost of $90 per scene. The French space agency, CNES, proposed a twofold arrangement to provide SPOT data to IGBP. Some SPOT scenes could be made available at a special price ($1200 per multispectral scene; $1500 per panchromatic scene) and a "limited number" of scenes would be made available at a reduced price of $200 per scene. The Indian Space Research Organization (ISRO) has offered IGBP researchers access, at a modest cost, to more than 10,000 scenes from the Landsat-thematic mapper, and IRS 1-A and 1-B data archived in digital form at the ISRO Centre in Hyderabad.

C. Biosphere-Atmosphere Field Experiment in Amazonia

39. In June 1992, at its third meeting in Greenbelt, Maryland (United States), the joint WCRP/IGBP Working Group on Land-Surface Experiments, suggested that a large-scale land surface experiment be conducted in Amazonia between 1997 and 1999. Meanwhile, the scientific plan has been further developed by the Brazilian National Space Research Institute (INPE). The main goals of the biosphere-atmosphere field experiment in Amazonia are to answer the following questions:

a) How does Amazonia currently function as a regional entity? This question addresses interactions with the Earth system in the form of exchanges of energy, water, carbon and other trace gases via atmospheric and river systems; and

b) How will human-induced change alter the function of the Amazon region? This question addresses modifications within Amazonia associated with replacing tropical forest with mixed replacement vegetation, and on indirect modification of the vegetation gradient in areas surrounding Amazonia.

40. To answer these questions, an experiment consisting of three linked field activities has been proposed: the Large-scale Atmospheric Moisture Balance of Amazonia using Data Assimilation (LAMBADA)

programme that constitutes the long-term monitoring and large-scale regional component of the experiment, the Biosphere-Atmosphere Transfers and Ecological In-Situ Studies (BATERISTA) programme and the Amazon Ecology and Atmospheric Chemistry Experiment (AMBIANCE), which represents the process-oriented field studies component of the experiment.

41. The LAMBADA programme would set in place a radiosonde network around and within the Amazon basin; precipitation, hydrography and surface meteorological networks within the basin; long-term monitoring stations of $C0_2$ and trace gases in at least six research sites within the basin; and a comprehensive satellite remote sensing programme. The field observation phase of LAMBADA would continue for approximately two years, probably in 1997 or 1998. In conjunction with meteorological fields provided by a mesoscale model 4-dimensional data assimilation (4DDA) scheme, LAMBADA would provide the data that would permit quantification of the energy, moisture and carbon budgets of the region and their dependence on the large-scale atmospheric circulation.

42. The BATERISTA programme is proposed as a coordinated set of process studies aimed at a better understanding of the micro-meteorological, eco-physiological and bio-geochemical controls on the exchange of energy, moisture, trace gases and momentum between the atmosphere and the vegetated land surface. The BATERISTA studies would also provide opportunities for the validation of remote sensing techniques and provide a framework for associated ecological studies. As proposed, six research areas located in different eco-climatic regions of the Amazon basin and surrounding regions are to be equipped with arrays of surface sampling equipment, flux towers and other hardware. Three of the research areas are to be the axis of an ecological gradient transect study.

43. The AMBIANCE programme is proposed as a study of the influence of the intact forest and of the consequences of forest conversion, agricultural practices and abandonment, and secondary succession, on regional and global biochemistry and atmospheric chemistry, focusing on ecosystems carbon dynamics, atmospheric greenhouse gases (CH_4, N_2O, CO_2) and the oxidizing potential of the atmosphere (O_3, CO, NMH, NO_x). Flux tower and aircraft gas concentration measurements, and satellite observations of land-use patterns will provide the basis for integrated measurements of fluxes at scales ranging from metres to kilometres in the Amazon basin. These data will be complemented with ecological monitoring studies along transects of climate and land-cover and land-use changes.

D. Use of meteorological satellite data for vegetation studies

44. Plans for a full suite of satellite-borne sensors in the late 1990s, specifically designed for environmental mapping and monitoring, are crucial to the success of IGBP. Yet there is also the potential for wider application of remote sensing systems that are already in operation, particularly the meteorological satellites operated by the United States National Oceanographic and Atmospheric Administration (NOAA). Although not originally intended for studies of global vegetation, the AVHRR sensor carried on the NOAA satellites detects radiation separately in the red and infrared parts of the spectrum. The red spectral measurements are sensitive to the chlorophyll content of vegetation, and the near infrared to the mesophile structure of leaves. Taken together, they provide information on a wide variety of important attributes of vegetation cover, including leaf area index, leaf biomass, net primary productivity and photosynthetic capacity. Methods are also being developed to use AVHRR data to determine land surface temperature, the extent and frequency of biomass burning (forest and grassland fires), and evaporation-transpiration rates.

45. A specific advantage of the AVHRR observation system is that it provides full global coverage every few days, greatly increasing the likelihood of obtaining a seasonal sequence of cloud-free images. In addition, there is a well established system of ground receiving stations for data capture and initial processing, with data archives that provide a record back to the early 1980s. The spatial resolution of AVHRR is around 1 km. This is relatively poor in comparison to Landsat and other satellite sensors; however, any finer

resolution would produce a large and unmanageable volume of data for global land cover studies (at least for current computing capabilities).

46. While the AVHRR data have been successfully used at the 1 km scale for subcontinental studies of vegetation properties and their temporal changes, the global data set is at present limited to 15-20 km resolution. Thus, there is a considerable potential for greater utilization at scales of ecological relevance. Ways to achieve that potential have recently been reviewed by the Land Cover Working Group of the IGBP Data and Information System, resulting in the following conclusions and recommendations:

a) A global data set of the land surface should be created from the AVHRR data around 1 km resolution, with full global coverage at least once every 10 days for at least a year. Such a data set would be of very great benefit to several IGBP Core Projects, notably GCTE, IGAC, BAHC and GAIM;

b) Substantial effort is required in the pre-processing of the data set (radiometric calibration, atmospheric correction, geometric correction and temporal composing), with several aspects requiring additional research before standard procedures can be established. It can then be determined how best to proceed with continuous monitoring of the Earth, year after year, at this resolution; and

c) A global facility will be required to ensure coordination between ground stations, and the creation of a uniform data set. Such a data set, when converted into information related to the attributes of the vegetation cover, would be of great benefit.

III. THE ROLE OF DEVELOPING COUNTRIES IN IGBP

A. Participation in START

47. So far, there has been only limited participation by scientists in developing countries with regard to international efforts dealing with climate variability and other aspects of global change. Yet their involvement is critical for an effective global scale approach to these problems, as stressed both in a United Nations General Assembly resolution (44/207 of 22 December 1989, "Protection of global climate for present and future generations of mankind") and by the Special Committee on the Participation of Developing Countries of the IPCC. This need is specifically addressed by the global change START of the IGBP, HDP and WCRP. START has initiated a process that will, in the short-term, provide direct assistance to the scientific community to narrow current uncertainties pertaining to global change, and, through stimulating global change research and assessment, also provide necessary information to governmental ministries and agencies involved in current negotiations arising from UNCED. In the long-run, START will lead to substantial capacity building, through the provision of training and education to the next generation of scientists in all countries, with special attention given to the needs of developing countries.

48. Specifically, START will involve the scientific communities within a region by: a) increasing their awareness of the importance of global change issues; b) training them in the multidisciplinary work necessary to implement global change projects; c) helping them to formulate appropriate projects to be carried out in regional or international collaboration; c) assisting them in obtaining adequate technical support to carry out regional interpretation, analysis and modelling through techniques such as remote sensing and the use of Geographic Information Systems; d) promoting collaboration between natural and social scientists on regionally relevant problems; e) providing them with the capability to access and manage appropriate regional databases, and to initiate the establishment of required databases that are not yet available; and f) promoting a dialogue between the scientific community and decision makers, at both national and regional levels.

49. Beneficiaries will also be national governments in the form of Ministries for Environment, Science and Education, Planning and Foreign Affairs, i.e., all those sectors involved in the international negotiations following UNCED, and the development of national responses to associated international agreements. In addition, START provides a mechanism that could be of great value for ministries or agencies for development cooperation, which have an interest in capacity building in the environmental field in developing countries.

50. The IGBP Core Projects and other programme activities benefit component national studies and individual researchers in many ways. The most important overall effect is to maximize scientific progress, at minimum extra cost. Thus a coherent international framework provides "added value" by increasing the productivity of the national effort. The way in which this is achieved varies according to the level of scientific development within a country, and the particular area of study. General benefits are that IGBP:

a) Assists the planning of national global change research programmes by providing a soundly-based, intellectual and organizational framework for focused research, with overall aims, priorities and implementation developed and endorsed by the international scientific community;

b) Adds to the scientific value of component studies, and helps in their interpretation, by providing complementary information; for example, by widening the range of studies, extending their temporal and spatial coverage, and, through inter-comparison exercises, testing models and improving their predictive power;

c) Promotes the rapid communication of scientific ideas and results from the most advance on-going scientific research, through meetings and publications, and by encouraging interdisciplinary liaison at the national, regional and international level between individuals and research groups;

d) Develops, and tests the applicability of, standard methods and protocols for measuring key environmental variables, thereby facilitating national and international quality control, inter calibration studies, and subsequent data exchange, synthesis and interpretation;

e) Assists in the cost-effective deployment of major capital equipment and facilities, by encouraging their collaborative use and efficient scheduling, and promoting the international transfer of technological expertise;

f) Makes available the data sets collected by the component projects and studies of IGBP, and assists in developing common data management strategies, in liaison with national and international data centres;

g) Encourages the full involvement of developing countries, and those with economies in transition, in global change research by promoting the establishment of regional research networks, capacity building through training, and by providing, wherever possible, financial assistance for developing country participation in major IGBP meetings;

h) Keeps the research community informed of developments within the programme through IGBP Reports, the Global Change Newsletter and other publications;

i) Ensures that close working links are developed with other relevant international programmes and projects, particularly those of the WCRP and the HDP, and with international assessment exercises, such as those of the IPCC;

j) Provides the scientific understanding needed for the development and implementation of international conventions and protocols addressing global environment issues; and

k) Promotes the concept of IGBP science, the results obtained from the programme, and their application, to decision-makers, funding agencies and inter-governmental organizations, thereby indirectly assisting in the further financial support of its component studies.

B. Factors that limit the participation of developing countries

51. During the first regional IGBP meeting for South America (São José dos Campos, Brazil, 1990), the following were noted to be factors that limit the more active participation of South American scientists in the disciplines related to the IGBP: a) lack of research funds to start new research projects or continue with existing ones; b) lack of graduate students, collaborators, technicians, etc.; c) over commitment in these research projects or other related teaching, professional and/or administrative duties; d) lack of confidence on the final destination of the results of their research, if they are merged with the worldwide information that will be assimilated into IGBP conclusions; and e) unstable political, labor or research conditions.

52. The economic limitations present in many developing countries have been recognized as the major cause for the lack of increased participation in the IGBP projects. For this reason, not only the search for external funds (i.e. from international organizations, private foundations, and governments of industrialized countries), but any efforts to promote the programme among the governments of the region are highly desirable. This would help scientists to obtain official recognition of the significance of the programme, and the importance of scientific activity for the planning of any local or regional development programmes. Fortunately, there are no serious linguistic or cultural barriers among the countries of the region. However, existing scientific groups in the region are highly sensitive to political and/or economic instability and have a strong tendency to disintegration due to the lack of adequate salaries and stimulation. As a consequence of recurring crises, researchers often leave the region for the more developed countries. The situation in South America is similar to that in other regions.

53. The lack of appropriate mechanisms to recognize creative contributions may prevent some scientists from contributing novel ideas to a project within the scope of the IGBP. Hypotheses and new ideas are the most important resources in science; therefore, scientists may hesitate to contribute ideas in the absence of a clear mechanism to show how their contributions will be recognized. Poor recognition of the IGBP at the national level may limit participation of some scientists, especially those in the institutes with a rigid research agenda.

54. In order to ensure an efficient participation of regional scientists, there is an urgent need to improve communication systems both within the region and with the scientific community outside the region. In addition, due to the lack of sophisticated analytical equipment, computers, etc., in many laboratories in the region, there is a need for the development of strong technological cooperation both within the region as well as with centres outside South America. The Core Projects and National Committees should identify such needs and take appropriate action to remedy the deficiencies.

55. There is an overall lack of scientists and technicians, especially in fields such as atmospheric chemistry and nuclear physics. There is also an absence of adequate training programmes in environmental science at universities and technical high schools. Insufficient library resources constitute another important limitation, as well as problems of acquisition, maintenance, and technology transfer of state-of-the-art equipment and instrumentation that is urgently needed to improve data collection and processing.

56. Some of these concerns were dealt with in later phases of the IGBP programme development (e.g. publication of results, access to databases etc.). Most of these concerns however are valid today and perhaps are typical for developing countries in other regions. Indeed, during the United Nations/International

Astronautical Federation (IAF) Workshop on "Organizing Space Activities in Developing Countries: Resources and Mechanisms" (Graz, Austria, October 1993), similar concerns were expressed. It was therefore agreed that it is extremely important to stimulate the participation of scientists from developing countries by means of: a) research grants; b) travel grants; c) personnel and equipment for research activities; c) scholarships for graduate students; d) access to research centers, data banks, working groups, etc., without financial conditions; and e) specific short-term research contracts.

C. Problems related to the access to environmental data

57. As an increasing number of States invest in ground receiving stations, it is vital that those investments not be rendered obsolete by incompatible new technologies. To this end, Member of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) have emphasized the importance of continuity and complementarity in remote sensing and meteorological satellite programmes. CEOS is the primary international mechanism for coordinating the planning of satellites with environmental applications and the compatibility of data formats. CEOS has been working to increase the dialogue between satellite planners and users including international user organizations, which now have affiliate status in CEOS, particularly with respect to environmental applications.

58. Practical and financial difficulties in gaining access to satellite data for environmental purposes has been a factor limiting the use of satellite data in many countries, particularly the developing countries; Member States of COPUOS have frequently expressed their concern over such high prices. Some actions have been taken to develop flexible pricing arrangements, including lower prices for research use, educational use and archival data. Arrangements are also being made to facilitate acquisition of data through a network of local agents and through electronic means. Recently, the United States National Aeronautics and Space Administration (NASA) has developed a project to this end.

59. NASA and other United States federal agencies maintain vast databases of remote sensing data for Earth and space sciences which have been gathered over the last 30 years. There is a wide range of accessibility to, and cost for the data. Some of these data are on-line and quickly accessible in standard formats at no cost to Internet users. Other data may be stored using old magnetic-tape formats, or may have other significant costs (e.g. from a few hundred to a few thousand US dollars per scene). Data holdings are in many forms and in many places throughout NASA Centers and other facilities. Further, these data holdings grow over time as new types of data are needed and the size of individual data sets continually increases as new data are received on a daily or even hourly basis, e.g. from remote sensing spacecraft. Finally, these data change as the organization of the digital libraries change or as format standards change.

60. For essentially all data, even for data not on-line, users can search an on-line directory, called the Master Directory, to learn what data are available, obtain brief information about them, where and how they may be ordered or accessed, and whom to contact for further information. To keep track of the data holdings, the Master Directory is accessible over Internet. Primarily, the directory identifies the discipline and selective parameters or type of data (e.g. atmospheric chemistry, infrared images, visible images), the time period of observations, and the particular repository or data center where the data can be found. Detailed instructions on the full range of Master Directory capabilities are found in the User's Guide: "Master Directory User's Guide, Alphanumeric Interface," which can be obtained from: NSFC NSSDC/Coordinated Request and User Support Office, CRUSO, Mail Code 633.4, Greenbelt, MD 20771 USA.

61. Most Earth science data are those associated with the Earth Observing System Data and Information System (EOSDIS), and the interagency system called the Global Change and Data Information System (GCDIS). These data include information about atmosphere, land, geology, oceans, and biological entities. Examples of data include chemical, radiation, vegetation, temperature, wind, and ocean height and current. These image-oriented data are organized into data sets, each for a particular type of sensing instrument and

geographic and temporal coverage. The databases are organized and stored at data centers called Distributed Active Archive Centres (DAACs), specializing in specific disciplines. Each data centre has associated scientific users and can provide expert assistance to users of their data holdings. The data provided by EOSDIS include Pathfinder data sets, which consists of long-term remotely sensed data from previous and currently operating satellites. Examples of such data sets are: global vegetation, global sea surface temperatures, global clouds radiation, and aerosols derived mostly from the NOAA and Landsat satellites.

62. The international dissemination of information on the peaceful uses of outer space has been one of the primary concerns of COPUOS since its inception in 1958. The Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82) recommended that an international space information service be established within the United Nations Office for Outer Space Affairs (OOSA). This service was to initially consist of a directory of sources of information and data services and would be available to all countries, particularly developing countries. The General Assembly, in resolution 37/90 of 10 December 1982 ("Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space"), endorsed that recommendation, and the Secretariat is working, to develop such a service. Because of the limited resources available, the full implementation of the International Space Information Service (ISIS) programme has been delayed.

63. Each year during the session of the COPUOS its Scientific and Technical Subcommittee, Member States, and particularly the developing countries, discuss the problems related to the non-restricted and non-expensive access to space-related information. To facilitate this process, the existing nucleus of ISIS within OOSA can be substantially expanded in cooperation with and with the support of other organizations. Possible next steps in this expansion could include:

a) Compilation of a list of activities and programmes conducted by different national and/or international organizations and agencies so as to provide a basis for better coordination;

b) Development of a database where data from different Earth observation systems can be obtained. This would help countries with little or no space research activity to gain access to valuable data;

c) Development of a database that will contain information for decision-makers;

d) Investigation of the role which the proposed regional centres for space science and technology education (see below) could play in disseminating and compiling Earth observation data; and

e) Development of databases with information on other space-related subjects, including space communication, meteorology, navigation and basic space science.

64. The further development of ISIS will provide all interested parties with direct access, through the Internet, to all information sources available. ISIS will also facilitate the search and selection of space-related information on behalf of Member States and will provide advice on how such information may best be utilized.

D. The role of the Centres for Space Science and Technology Education

65. While many students, educators and researchers from developing countries now go to developed countries for advanced training and research, such programmes are very expensive and can only accommodate a very limited number of people. A small number of developing countries are developing national educational programmes in space technology and applications, but most countries are not yet in a position to do so. The opportunities for appropriate advanced education at affordable cost for people from developing

countries could be substantially expanded through the establishment of regional educational programmes in developing countries that have the capability to support such programmes.

66. To this end, the United Nations, through OOSA, has begun an initiative to establish Centres for Space Science and Technology Education in each region covered by the United Nations Regional Commissions. The emphasis of the centres on educating educators will provide a multiplier effect to ensure a long-term, adequate supply of trained specialists in the various disciplines required for sustainable development and environmental monitoring .

67. The proposal for the establishment of the regional centres was endorsed by COPUOS in 1990 and subsequently approved by the General Assembly. Consultations have been held with interested countries in the developing regions and with developed countries that might support the centres. Evaluation missions have been undertaken to potential host countries for such centres in Latin America, Africa, Western Asia, Asia and the Pacific. Consultations are continuing to consider how best to establish the centres and ensure their long-term viability in meeting the needs of the countries of each region. During the next four years, INPE of Brazil will be the headquarters for the regional Centre for Space Science and Technology Education in Latin America and the Caribbean, which will be rotated every four years between Brazil and Mexico.

68. In the initial phase the centres will concentrate on providing an advanced education, research and applications development programme in remote sensing, satellite meteorology and geographic information systems. Improving data processing and information management capabilities in developing countries including archives of satellite data and links to international environmental databases such as UNEP's Global Resource Information Database (GRID), will be an important element of the centre's functions. The centres will therefore make a major contribution to meeting the need (as identified in Agenda 21 of UNCED) to develop the capacities of developing countries to participate effectively in the global effort to protect the environment and ensure the sustainable development of all countries.

69. In the area of Earth observation systems, for example, the programme of each regional Centre will:

a) Develop skills and knowledge of university educators, environmental research scientists and project personnel in remote sensing and related technologies for subsequent application in national development and environmental management programmes;

b) Assist educators to develop environmental and atmospheric sciences curricula that they can use to advance the knowledge of their students in their respective institutions/countries;

c) Develop the skills of environmental research scientists and project personnel in the design, development and application of remote sensing techniques in natural resources management and biodiversity protection;

d) Assist research scientists and project personnel in preparing space-derived information for presentation to the policy and decision makers in charge of national and regional development programmes;

e) Enhance regional and international cooperation in space science and technology programmes, particularly those that are related to environmental monitoring and natural resources management, and support and contribute to the work of institutions of higher learning in each region and the activities of national/regional remote sensing user assistance and training centres; and

f) Assist in disseminating to the general public, the value of space science and technology in improving their everyday quality of life.

70. In each region, the Centre will prepare and carry out annual education, research and applications programmes for university level educators and research and application scientists drawn from the user communities. The duration of each programme would be for a period of nine months. Experts and consultants contributing to the Programme will be highly qualified (scientific and technical) individuals from the countries of the region.

71. The programmes will focus on teaching techniques and methods in environmental information systems as applied to educational, environmental and economic development issues. Case studies using remote sensing and meteorological satellite data that can be processed, analyzed and stored on micro-computer systems will be prepared in advance to provide "hands-on" illustrations of applications to specific natural resource surveys and to specific environmental monitoring and assessment exercises.

72. Participants also will acquire knowledge and skills needed to develop and prepare teaching manuals, auxiliary audio visual materials, research and applications project proposals and reports. During the school vacation periods, two workshops for secondary and primary schoolteachers, each lasting a minimum period of two-weeks, will be organized on an annual basis. Participants in these workshops would be shown the relevance of remote sensing technology and other aspects of Earth observation systems to national development and environmental monitoring, and to the means and materials through which they could introduce these concepts into the secondary education curricula of their countries.

73. An integral part of each of these Centres for Space Science and Technology Education will be a Data Management Unit. Through this Unit, each Centre will have direct linkages with existing relevant global data centres and the nearest UNEP/GRID Centres. Such linkages will enable those participating in the programmes of these Centres to utilize the data in the archives of the data centres, particularly when they undertake projects that can benefit from their gaining such an access. Each Centre will have direct access to the Mercure satellite-based communications network proposed by European industry and ESA for the benefit of UNEP. The Mercure network would provide a modern, state-of-the-art global communication capability for the transfer of environmental data between different UNEP/GRID Centres and between databases and archives and users of environmental data.

74. The technical standards of the proposed network would match those of local G.Ss, used to analyze and process environmental data, with the capability to support computer file transfers, i.e. file transfer protocol (FTP), document transmission, voice communication, and video transmission including video-conferencing. The network would provide the Centres with timely access to environmental data including maps and images acquired from environmental satellites. Other important data made available through the Mercure network would concern environmentally-sound technologies and methods to safeguard the World's renewable resources. The network would also contribute to the development of better communication between regional Centres and could help to establish global teleconference sessions in order "to bring together" participants/instructors from all regional Centres to discuss important programme elements or to share practical experience.

75. Each Centre will also be equipped with an AVHRR receiving station. In addition, each Centre will be linked with the nearest Earth observation ground receiving station(s). The data collected from these stations will be used in the activities of each Centre and when deemed necessary, will also be part of the Centre's archives. Each Centre will establish a data management programme for the purpose of enhancing the skills of its user community in order that this community could have the capability to: a) develop guidelines for data collection; b) standardize their physical and socio-economic data collection process; c) develop guidelines for data geo-referencing; d) undertake the integration of socio-economic and bio-physical data through GIS; e) establish up-to-date national baseline information; and f) organize continuing education activities for policy/decision makers on the importance of data and its value and relevance in decision making.

76. Each of these regional Centres will be established in a major national science and technology-oriented university or research institution. Such an arrangement will enable the Centres to optimally utilize the existing professional staff and physical infrastructure at the host institution. The participants in the programmes of the Centres will also be able to collaborate with the graduates of existing training and user assistance centres on major research and application projects for the benefit of their countries. The establishment of the regional centres will require a strong commitment of support from the host countries as well as technical and financial assistance from developed countries and international organizations. Such assistance could take the form of full- or part-time technical specialists, data processing equipment and software, satellite data, funding for scholarships and other human, technical and financial resources.

IV. CONCLUSIONS

77. Now that IGBP research is well underway, greater emphasis needs to be given to coordination, time-scheduling and data management, and to ensuring that the necessary resources are secured for the core research that is essential for the attainment of the programme's long-term, global goals. IGBP research, primarily funded at the national level, involves several thousand scientists in over sixty countries. The international guidance for their work is provided by the SC-IGBP and its Secretariat, primarily acting through the SSCs, Standing Committees and CPOs of the programme's component projects. This organizational structure has a catalytic role, and is closely involved in the interpretation, synthesis, assessment and communication of results.

78. The importance of the IGBP initiative and its achievements to date have been widely acknowledged and formally recognized at both the governmental and intergovernmental level. Its main work phase, with all established Core Projects operational, is just beginning. However, existing support is inadequate for full implementation. For that to be achieved, there must now be a long-term commitment to support both the research and its international infrastructure. The lack of funding for either component would seriously jeopardize the success of the programme.

79. Three-fifths of the land area and nearly all of the rich and varied tropical regions of the globe, which are also the repository of the bulk of global genetic diversity, are occupied by developing countries. They have the privilege and responsibility to study and understand this global environment scientifically. The applications and benefits from such a understanding are immediate and immeasurable.

80. Recognizing that developing countries are the most vulnerable to the impact of global changes both in terms of economics and human welfare, and recognizing that IGBP provides a unique opportunity for developing countries to build an expert and self-reliant capacity in the interdisciplinary field of basic sciences, environment and development, all developing countries are encouraged to join IGBP and participate in it. There must be a national commitment to the programme and at least modest resources made available to their scientists. It is, however, the responsibility of scientists from developing countries to ensure that the decision makers in their respective countries are made aware of the potential benefits of the IGBP and that support of these activities is in their overall national interest.

81. In view of the objectives and intrinsic scientific content of IGBP, as well as its intensely interdisciplinary nature, training has become a decisive element. It covers different levels: researchers, technicians, and managers. It requires training opportunities at the national, regional and international levels; and it involves different scientific areas, core projects, techniques and methods.

82. An important requirement of IGBP activities is a scientific and studied utilization of remote sensing data for a wide variety of purposes. To do this effectively, scientists from developing countries will require

suitable training, access to data (preferably free of charge), and opportunities for regional and global cooperation.

83. To facilitate the process of increasing the participation of developing countries in the IGBP programme, as well as in other programmes and projects involving space research and applications, the United Nations Committee on the Peaceful Uses of Outer Space and its subsidiary bodies should make specific recommendations, based on their deliberations. COPUOS may wish, for example, to recommend the extension of the International Space Information Service of the Secretariat to better serve the need for coordinating and expediting access to environmental data bases and other sources of information. Similarly, the role of the proposed Centres for Space Science and Technology Education in assisting IGBP activities of developing countries should be explored in more detail.

LIST OF ACRONYMS

ACE - Advisory Committee on the Environment
AMBIANCE - Amazon Ecology and Atmospheric Chemistry Experiment
APN -Asia-Pacific Network for Global Change Research
ASEAN - Association of Southeast Asian Nations
AVHRR - Advanced Very High Resolution Radiometer
BAHC - Biospheric Aspects of the Hydrological Cycle (of IGBP)
BAKOSURTANAL - National Coordinator for Survey and Mapping Agency (of Indonesia)
BATERISTA - Biosphere-Atmosphere Transfers and Ecological Research In situ Studies
BMG - Meteorological and Geophysical Agency (of Indonesia)
ENSO - El-Niño Southern Oscillation
CEOS - Committee on Earth Observation Satellites
CGCR - Committee on Global Change Research (in the United States)
COPUOS - Committee on the Peaceful Uses of Outer Space (of United Nations)
CPO - Core Project Office (of IGBP)
DCP - Data Collection Platform
ENRICH - European Network for Research in Global Change
EOS - Earth Observing System
EOS-DIS - EOS Data and Information System
ERS - European Remote Sensing Satellite
FAO - Food and Agriculture Organization
FCCC - Framework Convention on Climate Change
GAIM - Global Analysis, Interpretation and Modelling
GAW - Global Atmosphere Watch
GCDIS - Global Change Data and Information System
GCOS - Global Climate Observing System
GCTE - Global Change and Terrestrial Ecosystems (of IGBP)
GEMS - Global Environment Monitoring System
GEWEX - Global Energy and Water Experiment
GIS - Geographical Information System
GLOCHANT - Global Change and the Antarctic
GOES - Geostationary Operational Environmental Satellite (of NOAA)
GOEZS - Global Ocean Euphotic Zone Study (of IGBP)
GOOS - Global Ocean Observing System
GRID - Global Resource Information Database (of UNEP)
GTOS - Global Terrestrial Observing System
HDP - Human Dimensions Programme (of Global Environmental Change Programme)
HRPT - High Resolution Picture Transmission
IAI - Inter-American Institute for Global Change Research
IAF - International Astronautical Federation
ICACGP - International Commission on Atmospheric Chemistry and Global Pollution
ICSU - International Council of Scientific Unions
IGAC - International Global Atmospheric Chemistry Project (of IGBP)
IGBP - International Geosphere-Biosphere Programme
IGBP-DIS - IGBP Data and Information System
IGFA - International Group of Funding Agencies
IOC - Intergovernmental Oceanographic Commission (of UNESCO)
IPCC - Intergovernmental Panel on Climate Change
IRS - Indian Remote Sensing Satellite
ISIS - International Space Information Service

ISRO - Indian Space Research Organization
ISSC - International Social Sciences Council
JERS - Japanese Earth Resources Satellite
JGOFS - Joint Global Ocean Flux Study (of IGBP)
LAMBADA - Large-scale Atmospheric Moisture Balance of Amazonia using Data Assimilation
LANDSAT - Land Remote Sensing Satellite
LAPAN - National Aeronautic and Space Agency (of Indonesia)
LOICZ - Land-Ocean Interaction in Coastal Zone (of IGBP)
LUCC - Land Use/Cover Change (of IGBP)
MOS - Marine Observation Satellite (of Japan)
MST - Ministry of Science and Technology (of India)
NATT - Northern Australia Tropical Transect
NC - National IGBP Committee
NOAA - National Oceanic and Atmospheric Administration (USA)
NRC - National Research Council (United States)
OOSA - Office for Outer Space Affairs (of the United Nations Secretariat)
PAGES - Past Global Changes (of IGBP)
SAC - Scientific Advisory Council (of IGBP)
SARCS - Southeast Asian Regional Committee for START
SLR - Sea Level Rise
SC-IGBP - Scientific Committee for the IGBP
SCAR - Scientific Committee on Antarctic Research) (of ICSU)
SCOPE - Scientific Committee on Problems of Environment (of ICSU)
SCOR - Scientific Committee on Oceanic Research
SPARC - Stratospheric Processes and their Role in Climate
SPOT - System Probatoire d'Observation de la Terre (French remote sensing satellite)
SRAVAN - Society for Relief Avoidance and Vigilance Against Natural Disaster (Bangladesh)
SSC - Scientific Steering Committee (for GCTE of IGBP)
START - System for Analysis, Research and Training (of Global Change, IGBP)
TEACOM - Regional Committee for Temperate East Asia (of START)
UNCED - United Nations Conference on Environment and Development
UNEP - United Nations Environment Programme
UNESCO - United Nations Education, Science and Cultural Organization
VHRR - Very High Resolution Radiometer
WCRP - World Climate Research Programme (of ICSU)
WMO - World Meteorological Organization
WWW - World Weather Watch

SELECTED BIBLIOGRAPHY

United Nations Publications

Centers for Space Science and Technology Education: Capability Development in and Data Management for Environmental Assessment and Natural Resources Management, Document A/AC/105/534, United Nations 1993.

Gagliardini, D., Contribution of NOAA-A VHRR Data in Resources Management, Environmental Assessment and Global Change Studies in the Southern Region of South America, in *Seminars of the United Nations Programme on Space Applications,* No. 4, p. 187, United Nations document A/AC.105/532, United Nations 1993.

The Role of the Committee on the Peaceful Uses of Outer Space in Implementing the Recommendations of the United Nations Conference on Environment and Development, Report by the Secretariat, United Nations document A/AC/105/547 and Add..1,
United Nations, 1993.

Strömquist, L., Larsson, R., Rydén, A., A Practical Approach to Remote Sensing for Environmental Monitoring in Developing Countries, in *Seminars of the United Nations Programme on Space Applications,* No. 5, p. 119, United Nations document A/AC.105/568, United Nations 1994.

Towards a Global Terrestrial Observing System (GTOS). Detecting and Monitoring change in Terrestrial Ecosystems, Report of a Workshop in Fontainebleau, France (27-31 July 1992). MAB Digest 14, IGBP Global Change Report 26, UNESCO 1993.

Other Publications

Costanza, R., Norton, B. G., Haskell, B. D. (Ed.), *Ecosystem Health. New Goals for Environmental Management,* Island Press, Washington, D. C., Covelo California, 1992.

Desai, Pranav S., Joseph, George, Satellite Observations for the Study of Global Change, *Indian Journal of Radio Space Physics*, Vol. 23, pp. 101-124, April 1994.

Duchossois, G., The Contribution of ERS-1 and ERS-2 to Global Change and Environmental Monitoring, paper IAF-94-B.6.115, 45th International Astronautical Congreess, Jerusalem 1994.

Geyer, R. A. (Ed.),., *A Global Warming Forum: Scientific, Economic and Legal Overview,* CRC Press, Boca Raton, 1993.

Global Change, Science and ICSU, *Science International Newsletter,* No. 41,
ICSU September 1990.

Global Change Newsletter, No. 18, IGBP Secretariat, Stockholm, Sweden, May 1994.

Global Climate Change. A Scientific Review Presented by The World Climate Research Programme, WMO and ICSU, January 1990.

Gupta, R.K., Sesha Sai, M.V.R, Potential of Satellite Based Systems for IGBP Studies and the Facilities Available in India, *Asian-Pacific Remote Sensing Journal*, July 1994.

Hoepffner, N., Baker, T., Van Camp, L., Nykjaer, L., Schlittenhardt, P., and Murray, C. N., "Marine Productivity Along the Northwest Coast of Africa (Mauritania): Estimation from Satellite Data" in: *Environmental Observation and Climate Modelling through International Space Projects, Proceedings of the European "International Space Year" Conference, Munich, Germany, 30 March - 4 April 1992*, ESA ISY-1, Vol. 1, 1992.

Holmes, G., Theodore, L., Singh, B., *Handbook of Environmental Management and Technology*, Wiley, New York, 1993.

IGBP in Action: Work Plan 1994 - 1998, *Global Change Report*, No. 28, Stockholm, 1994.

International Program for Earth Observations, Final Program, *The International Space University, Summer Session*, Toronto, Canada 1990.

Global Change, *IGBP Reports* No. 1 - 31, Stockholm, 1986 - 1994.

Keating, M., *The Earth Summit's Agenda for Change: A Plain Language Version of Agenda 21 and the Other Rio Agreements*, Centre for Our Common Future, Geneva, 1993.

Lee, C. C., *Environmental Engineering Dictionary*, Government Institutes, Rockville, Md. 1992.

Mooney, H. A., Fuentes, E. R., Kronberg, B. I., *Earth System Responses to Global Change: Contrast Between North and South America*, Academic Press, San Diego, 1993.

Proceedings of Asian Symposium on Global Environmental Change, Tokyo, 1-2 December 1992, Center for Global Environmental Research, National Institute for Environmental Studies, Environmental Agency of Japan, 1993.

Wertz, J. R., Larson, W. J., *Space Mission Analysis and Design*, Kluwer Academic Publishers, 1991.